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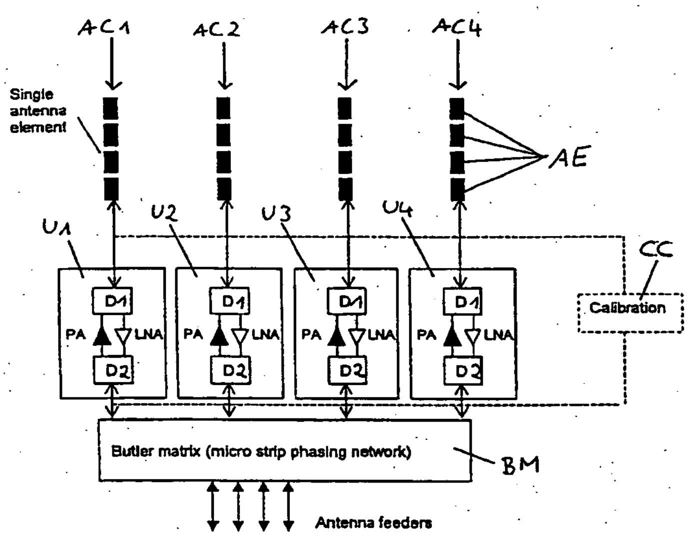
(54) Title: FIXED BEAM ANTENNA ARRAY, BASE STATION AND METHOD FOR TRANSMITTING SIGNALS VIA A FIXED BEAM ANTENNA ARRAY



(57) Abstract: The invention relates to a fixed beam antenna array and a base station comprising such an antenna array. In order to provide a simpler and more efficient fixed beam antenna array it is proposed that the array comprises columns (AC1-AC4) of antenna elements (AE) for transmitting generated signals, the fixed beam antenna array comprising moreover beamforming means (BM) for adjusting phase angle and/or amplitude of the generated signals and active power amplifiers (PA) respectively assigned to said columns (AC1-AC4) of antenna elements (AE) and arranged between said beamforming means (BM) and said columns (AC1-AC4) for amplifying the signals outputted by said beamforming means (BM) and for forwarding the amplified signals to the antenna elements (AE) destined for the transmission of the signals. The invention equally relates to a method for transmitting generated signals via such a fixed beam antenna array.

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Fixed beam antenna array, base station and method for transmitting signals via a fixed beam antenna array

The invention relates to a fixed beam antenna array and to a base station of a mobile communication network, in particular a cellular mobile communication network, with beam selection. The invention equally relates to a method for transmitting signals via a fixed beam antenna array.

In base station site solutions, efforts are made to increase the antenna efficiency, since increased efficiency enables fewer base station sites or smaller antenna panels. Moreover, a smaller base station total power can be achieved. Another reason for aiming at increasing the antenna efficiency is that in future the downlink capacity may be the limiting factor, especially when the internet type of data is becoming popular. This concerns in particular CDMA (Code Division Multiple Access)-systems.

Two different approaches are employed for increasing the downlink capacity in a base station site where antenna arrays are used for sectorised coverage: making the sectors narrower or using beamforming techniques. By feeding an antenna array with signals that are phase angle and/or amplitude shifted against each other, the power of transmitted signals of an antenna array is not homogeneously spread into the whole sector but directed in beams. A beam in this sense is a region of high signal strength.

One beam forming technique known from the state of the art is the fixed beam (or smart antenna) approach, which makes use of passive beamforming means like a Butler matrix. Such a technique is described for example in a product sheet "Smart Antenna Module" by Northern Telecom Europe Limited, 1992. Fixed beams have a dedicated direction and mobile stations being allocated in the sector of a directed beam use the available channels of this beam. In case the mobile station moves through a sector and leaves the sector of coverage of one beam, handover procedures ascertain that the mobile station uses the available channels of the next beam. The signals generated in the base station are passed on via power amplifiers to a Butler matrix, where the signals to be applied to the antenna elements are adjusted in order to form the selected beam. The fixed beam approach has the advantage that no antenna calibration is needed. It has the disadvantage, however, that beam specific power amplifiers designed for high power levels are required. This means that the power amplifiers do not work linearly, which makes necessary measures of linearisation.

Another known concept is embodied in active antenna systems, e.g. the Raytheon antenna systems, which comprise ordinary sector antennas with integrated PAs and LNAs.

A further known beam forming technique is digital beamforming. In this case the beamforming means is a digital beamformer, the outputted beams being fully steerable. The direction of the beam can therefore be adapted to transmission needs. The beam may for example move along with a mobile station through the whole sector of coverage of the antenna array. Digital beamforming

requires calibration of the power amplifiers but is more flexible and allows more uniform power distribution over linear power amplifiers. This approach would be rather expensive to implement with some systems, though. WCDMA (Wide Band Code Division Multiple Access) for example sets certain requirements for digital beamforming like that the antenna signals should be multiplied by the complex weights on chip level, which applies also to the tracking of the direction of the mobile station. Accordingly, this approach cannot be applied effectively on user by user basis.

Today's single sector antenna has usually 8-20 antenna elements connected in a form of a vertical column. The more elements in a column the narrower is the beam vertically and the greater is the antenna gain. Vertical beam width is usually 5-10 degrees while the horizontal beam width may be e.g. 65-110 degrees. Thus, if a multibeam antenna array is desired with narrow beamwidth for a macro site the antenna panel may include for example a 4x20 or a 8x12 matrix of antenna elements.

It is the object of the invention to provide a simpler and more efficient fixed beam antenna array with integrated active elements, a base station with beam selection and a method for transmitting signals via a fixed beam antenna array.

This object is reached on the one hand by a fixed beam antenna array with at least one column of antenna elements for transmitting generated signals, each column comprising at least one antenna element, the fixed beam antenna array comprising beamforming means for adjusting phase angle and/or amplitude of at least one of said generated signals, and at least one active power

amplifier respectively assigned to one of said columns of antenna elements and arranged between said beamforming means and said columns for amplifying the signals outputted by said beamforming means and for forwarding the amplified signals to the column of antenna elements to which it is assigned.

There may be several power amplifiers PA provided per column or one PA for several columns. The upper limit is preferably - but not necessarily - one PA for each antenna element, respectively. The lower limit is preferably defined by one PA per antenna column. Defining the number of PAs for a particular antenna arrangement is an optimisation problem.

On the other hand, the object is reached by a base station of a mobile communication network, in particular a cellular mobile communication network, comprising a fixed beam antenna array according to one of the preceding claims and a transceiver unit generating signals to be transmitted by the fixed beam antenna array and receiving signals received by the fixed beam antenna array.

Finally, the object of the invention is reached by a method for transmitting generated signals via a fixed beam antenna array with at least one column of antenna elements, each column comprising at least one antenna element, the method comprising the following steps:

a) adjusting phase angle and/or amplitude of at least one of said generated signals in a beamforming means (BM) for a specific one of the columns of antenna elements in order to form beams;
b) amplifying the signal outputted by the beamforming means by a phase calibrated active power amplifier

assigned to said specific column of antenna elements; and

c) transmitting the amplified signals via the antenna elements of said column of antenna elements.

The fixed beam antenna array, the base station and the method according to the invention combine the advantages of active and passive smart antennae. More precisely, the solution according to the invention takes advantage of the increased antenna gain of the narrow beams of smart antenna arrays and of significantly lower power levels per PA unit than with active antennas.

The narrow beams achieved by the passive beamforming means lead to an increased antenna gain, the low powers of each antenna element being coherently combined in the radio path. Especially for WCDMA, an increased downlink capacity is achieved. Narrow beams moreover lead to a decreased total base station power. Four beams mean e.g. a four-fold decrease in power.

In contrast to the known fixed beam antenna arrays, however, the power amplifiers employed are active power amplifiers and situated on the antenna side of the beamforming means. The power amplifiers are therefore antenna specific, not beam specific. This way, the decreased total power can be distributed evenly to a large number of small power power amplifiers, which leads to a power balance between the amplifiers and to a significantly smaller power level per amplifier than with smart antenna arrays. In smart antenna arrays, with the power amplifiers situated on the base station side of the beamforming means, the power in each power amplifier depends on how many mobiles are in the beam served by that power amplifier. If the mobiles all cluster in one

beam, all the transmission power has to be supplied by one power amplifier.

If, e.g., eight antennae are employed with a total power of 20 W, the array according to the invention needs eight 2.5 W amplifiers (8x2,5 W). In the case of known smart antenna arrays, however, power amplifiers are beam specific. When all mobile stations are in the same beam, a power amplifier with a power of 20 W is needed for this beam. This means, in the worst case eight 20 W power amplifiers (8x20 W) are needed.

With the antenna array, base station and method according to the invention, the power level of a single power amplifier can be designed to such a low value, e.g. less than 1 W, that linearisation is not required. The resulting low joint temperature moreover leads to a high reliability of the antenna array and a large MTBF (Mean Time Between Failure). In addition, the losses in the beamforming means can be avoided, since with the power amplifiers situated on the antenna side, there is no high power fed into the beamforming means. Because of the number of splitters, phase shifters and combiners in beamforming means like a Butler matrix, the power loss in known fixed beam antenna arrays can be significant.

Furthermore, a modular solution is obtained, which means a varying number of similar units can be employed, adapted to the needs of the respective base station. This allows a simplified construction of antenna arrays. In the whole, the proposed solution allows a simpler and more efficient design of antenna arrays and base stations as well as a simpler and more efficient method, in which the same baseband engine can operate active fixed beams or ordinary diversity branches. If e.g. dual branch diversity is required, then e.g. dual polarized antenna

elements AE may be used. In that case also the BM, the U unit and the CC unit have to be provided twice.

Advantageous embodiments of the invention become apparent from the sub claims.

In an advantageous embodiment of the antenna array and the base station according to the invention, the antenna elements, the beamforming means and the power amplifiers are integrated on the antenna panel.

Preferably, the beamforming means is an analogue phasing matrix, in particular a Butler matrix, especially a micro strip phasing network. Digital beamforming, e.g. a digital Butler matrix) can also be applied.

In a preferred embodiment, the antenna array is not only employed for transmission but also for reception of signals. Accordingly, reception branches are comprised for receiving signals via the antenna elements of the antenna columns. Each reception branch comprises a low noise amplifier for increasing the reception quality of the received signals. In order to be able to separate transmit Tx branches and receive Rx branches, each low noise amplifier is connected together with one of the power amplifiers respectively via duplexers to one of the columns of antenna elements on the one hand and the beamforming means on the other hand.

Since cable attenuation is compensated by the units formed by a low noise amplifier and a power amplifier respectively, thinner and cheaper cables can be used.

Low noise amplifiers and duplexers are preferably also integrated on the antenna panel.

Since the power amplifiers are positioned on the antenna side of the beamforming means, they have to be calibrated in phase by a calibration circuit. This is essential because the channels of the signals have to be exactly in the same phase at each antenna element of the antenna array. In known fixed beam antenna arrays a calibration is not necessary, since the signals are amplified before entering the beamforming means, the channels being provided to the antenna elements directly by the beamforming means. A calibration may be achieved with a calibration circuit or by accordingly matching the low noise amplifier/power amplifier units.

If a calibration circuit is used, it is preferably integrated in the antenna panel. This leads to a compact calibration structure with small calibration loops and enables an increased integration. In addition, no cables are required for calibration between the base station and the antenna panel.

In the case that all relevant elements are integrated in the antenna panel, the antenna panel is an independent unit which can be connected to any base station being able to handle a certain number of antenna ports. Moreover, by such an integration, i.e. in the case that analog beamforming means are in a mast, the baseband ASIC requirements are reduced in comparison to digital beamforming means at baseband.

The fixed beam solution according to the invention is particularly suited for WCDMA and GSM (Global System for Mobile Communication), in particular EDGE (Enhanced Data rates for GSM Evolution).

WCDMA and smart antenna arrays for GSM requiring multicarrier power amplifiers both need linearised power amplifiers. Moreover, WCDMA uplink coverage and downlink capacity can be increased with the solutions according to the invention.

For the GSM system the bandwidth of a single carrier is about 200kHz. The production of a multicarrier power amplifier PA for the GSM system is in principle easier than for the WDMA system where a single carrier covers about 5 MHz bandwidth. The design difficulty strongly depends on the actually used modulation sheme. Thus, e.g. for GSM modulation and specification the design is difficult. Multicarrier power amplifiers can also be designed for WCDMA; the design becomes easier when the power levels are reduced.

In the following, the invention is explained in more detail with reference to drawings, of which:

Fig. 1 shows an antenna array according to the invention; and

Fig. 2 shows an antenna array according to the invention in more detail.

Figure 1 depicts a four-beam antenna array of a macro site base station with a two-dimensional matrix of antenna elements AE.

The matrix is made up of four columns AC1-AC4 of antenna elements AE arranged on an antenna panel AP. Each column AC1-AC4 comprises four antenna elements AE. Each of the columns AC1-AC4 is connected to a unit U with low noise amplifiers, active, linear power amplifiers, duplexers and filters. A calibration circuitry CC has access to the

inputs and outputs of the unit U. The unit U is moreover connected to a Butler matrix BM.

The unit U comprising low noise amplifiers, power amplifiers, duplexers and filters is integrated on the antenna panel AP. Equally, the calibration unit CU and the Butler matrix BM are integrated on the antenna panel AP.

The functioning of the antenna array of figure 1 is the following:

A transceiver unit (not shown) of the base station generates signals that are to be transmitted and processes signals received by the antenna elements AE.

The transceiver unit forwards the generated signals to the Butler matrix BM. The Butler matrix BM adjusts the phase angle and/or the amplitude of the signals to be applied to the antenna elements AE for transmission, thereby enabling a transmission with fixed beams, the narrow beams resulting in an increased antenna gain. Significant losses in the Butler matrix BM are avoided, since no high power is fed into the Butler matrix BM.

The duplexers of the unit U comprise separate transmit Tx branches with power amplifiers and receive Rx branches with low noise amplifiers.

The signals outputted by the Butler Matrix BM are forwarded by the duplexers to the active power amplifiers, where they are amplified. The amplified signals are then passed on to the corresponding antenna elements AE for transmission. The total base station transmission power is divided evenly between all power amplifiers, therefore the power level of the power

amplifiers can be even less than 1 W. Accordingly, linearisation for the power amplifiers is not needed.

The signals received by the antenna elements AE are forwarded via duplexers of unit U to the filters and the low noise amplifiers. The low noise amplifiers increase the reception quality of the signals, before passing them on via the Butler matrix BM to the transceiver unit for further processing.

Both, the transmit as well as the receive signals are band-pass filtered by the filters in the U unit.

The calibration circuitry CC is provided for calibrating the whole unit U comprising low noise amplifiers, power amplifiers, duplexers and filters. More specifically, the unit U makes sure that the phase angle of each branch from the butler matrix BM to the corresponding antenna column AC 1...4 is within calibration accuracy. Thus, the phase shifts that were set by the BM for each branch remain the same at the antenna columns. Calibration should compensate for the phase shifts not only due to the power amplifiers PAs but also due to the duplexers, the filters and the LNAs.

Figure 2 shows a fixed beam antenna array according to the invention in more detail, illustrating the modular design of the antenna array. Corresponding elements are designated with the same reference signs as in Figure 1.

Again, four antenna columns AC1-AC4 are provided, each comprising four single antenna elements AE. To each antenna column AC1-AC4 there is assigned a power amplifier/low noise amplifier unit U1-U4 serving the four antenna elements AE of the respective column AC1-AC4. In addition to a power amplifier PA in a transmit branch and

a low noise amplifier LNA in a receive branch, each power amplifier/low noise amplifier unit U1-U4 comprises two duplexers D1,D2. One of the duplexers D1 connects the power amplifier PA and the low noise amplifier LNA with the antenna column AC1-AC4 and the other duplexer D2 connects the power amplifier PA and low noise amplifier LNA to a Butler matrix BM made up of a micro strip phasing network. The duplexers D1,D2 ensure that only the signals to be transmitted are amplified by the power amplifier PA and that only the received signals are processed by the low noise amplifier LNA. All power amplifier/low noise amplifier units U1-U4 have an identical design, allowing a simplified construction of different antenna arrays. The total transmission power is distributed equally on all four power amplifiers PA and the transmission power in each power amplifier PA is minimised.

The Butler matrix BM is moreover connected to antenna feeders, by which signals are provided to and received from the Butler matrix BM.

As described above by referring to Figure 1, the power amplifier/low noise amplifier units U1-U4 are calibrated by the calibrating circuitry CC, in order to ensure that the phase angle of each branch from the butler matrix BM to the corresponding antenna column AC 1...4 is within calibration accuracy.

The functioning of the fixed beam antenna array of figure 2 is basically the same as the functioning of the antenna array in figure 1.

Usually 4-20 antenna elements form one single column. However, in a preferred embodiment, each power amplifier serves several antenna elements. However, if each unit

would serve only one or two antenna elements, more power amplifiers would be required but the power per power amplifier could be further decreased. This is actually an optimisation problem in which such power amplifiers are to be employed which do not need linearisation and which are to run at a power level which gives good efficiency and reliability.

Other electronics such as up/down converters could be integrated in the antenna. Similarly, digital beamforming electronics could be integrated in the antenna and employed instead of the analog Butler matrix.

Claims

1. Fixed beam antenna array with at least one column (AC1-AC4) of antenna elements (AE) for transmitting generated signals, each column (AC1-AC4) comprising at least one antenna element (AE), the fixed beam antenna array comprising

   - beamforming means (BM) for adjusting phase angle and/or amplitude of at least one of said generated signals; and

   - at least one active power amplifier (PA) respectively assigned to at least one of said columns (AC1-AC4) of antenna elements (AE) and arranged between said beamforming means (BM) and said columns (AC1-AC4) for amplifying the signals outputted by said beamforming means (BM) and for forwarding the amplified signals to the column (AC1-AC4) of antenna elements (AE) to which it is assigned.

2. Fixed beam antenna array according to claim 1, characterised in that the beamforming means (BM) is an analogue phasing matrix.

3. Fixed beam antenna array according to claim 2, characterised in that analogue phasing matrix is a Butler matrix (BM), in particular a micro strip phasing network.

4. Fixed beam antenna array according to claim 1, characterised in that the beamforming means (BM) is embodied digitally.

5. Fixed beam antenna array according to one of the preceding claims, characterised in that the antenna elements (AE), the beamforming means (BM) and the power amplifiers (PA) are integrated on the antenna panel (AP).

6. Fixed beam antenna array according to one of the preceding claims, characterised by a phase calibration circuitry (CC) for calibrating the active power amplifiers (PA).

7. Fixed beam antenna array according to claim 6, characterised in that the phase calibration circuitry (CC) is integrated on the antenna panel (AP).

8. Fixed beam antenna array according to one of the preceding claims, characterised by reception branches for receiving signals via the antenna elements (AE) of the columns (AC1-AC4) of antenna elements (AE), each reception branch comprising a low noise amplifier (LNA), and each low noise amplifier (LNA) being connected together with one of the power amplifiers (PA) respectively via duplexers (D1,D2) to an assigned of the column (AC1-AC4) of antenna elements (AE) on the one hand and to the beamforming means (BM) on the other hand.

9. Fixed beam antenna array according to claim 8,
c h a r a c t e r i s e d i n t h a t
the low noise amplifiers (LNA) and the duplexers (D1,D2) are integrated on the antenna panel (AP).

10. Fixed beam aantenna array according to one of the preceding claims,
c h a r a c t e r i s e d i n t h a t
the power amplifier (PA) is embodied as multicarrier power amplifier.

11. Use of a fixed beam antenna array according to one of claims 1 to 10 in GSM, in particular EDGE, or WCDMA.

12. Base station of a mobile communication network, in particular a cellular mobile communication network, comprising a fixed beam antenna array according to one of the preceding claims and a transceiver unit generating signals to be transmitted by said fixed beam antenna array and receiving signals received by said fixed beam antenna array.

13. Base station according to claim 12,
c h a r a c t e r i s e d b y
a baseband engine able to operate active fixed beams or ordinary diversity antennas.

14. Use of a Base station according to claim 12 or 13 in GSM, in particular EDGE, or WCDMA.

15. Method for transmitting generated signals via a fixed beam antenna array with at least one column (AC1-AC4) of antenna elements (AE), each column

(AC1-AC4) comprising at least one antenna element (AE), the method comprising the following steps:

a) adjusting phase angle and/or amplitude of at least one of said generated signals in a beamforming means (BM) for a specific one of the columns (AC1-AC4) of antenna elements (AE) in order to form beams;

b) amplifying the signal outputted by the beamforming means (BM) by a phase calibrated active power amplifier (PA) assigned to at least said specific column (AC1-AC4) of antenna elements (AE); and

c) transmitting the amplified signals via the antenna elements (AE) of said specific column (AC1-AC4) of antenna elements (AE).

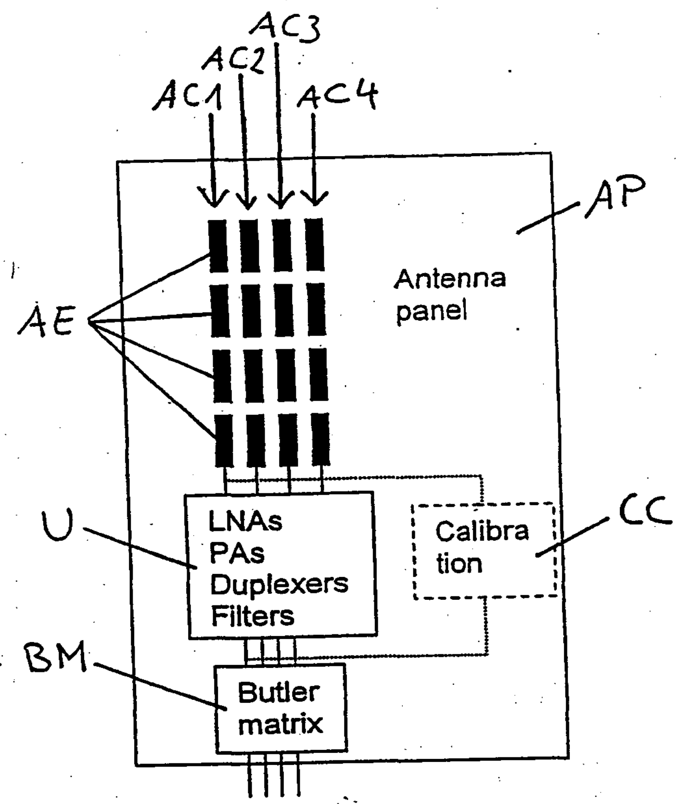
AC1
AC2
AC3
AC4
AP
Antenna panel
AE
U
LNAs
PAs
Duplexers
Filters
Calibra tion
CC
BM
Butler matrix

FIG. 1

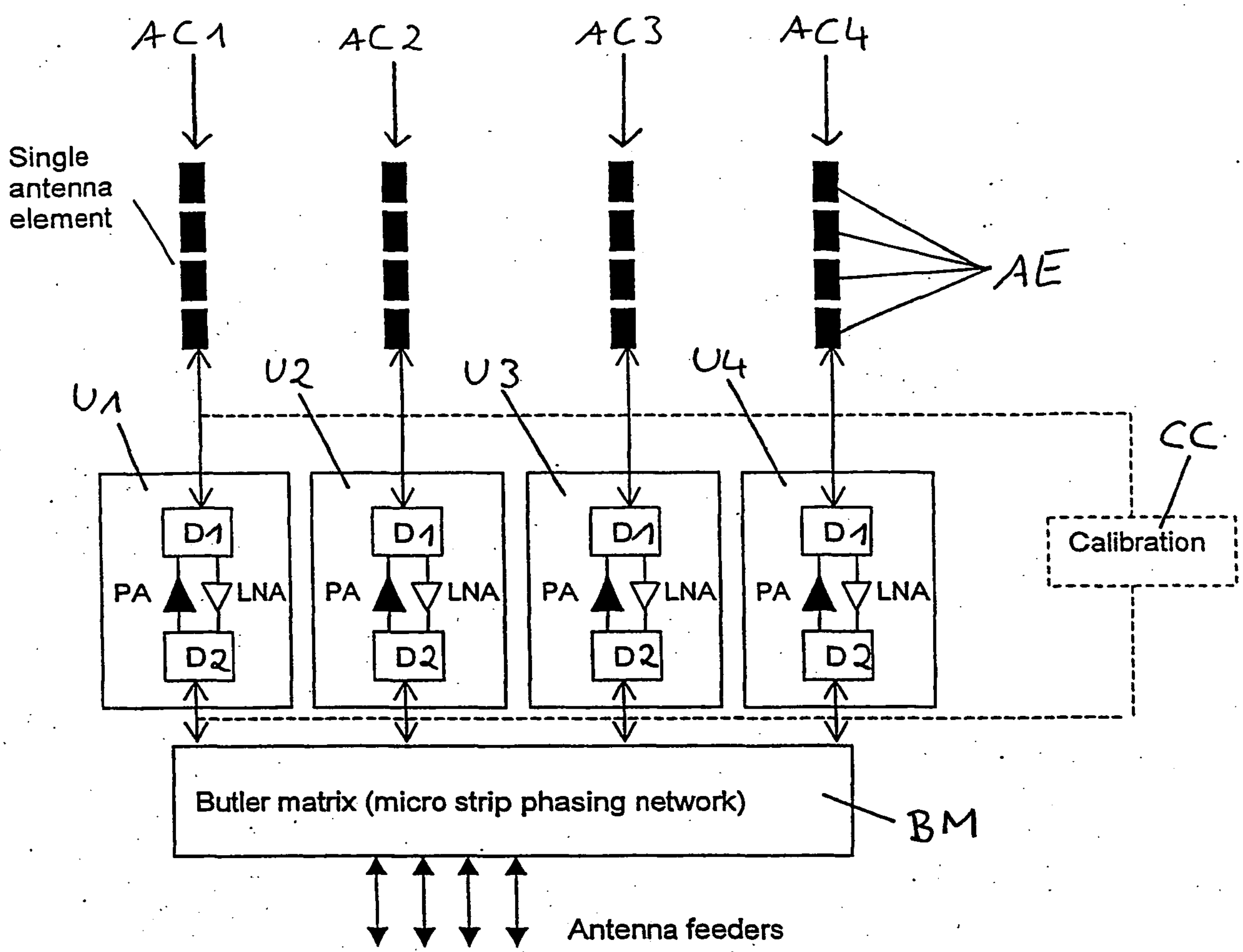
AC1
AC2
AC3
AC4
Single antenna element
AE
U1
U2
U3
U4
CC
D1
PA
LNA
D2
Calibration
Butler matrix (micro strip phasing network)
BM
Antenna feeders

FIG. 2

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 00/08583

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01Q23/00 H01Q1/24 H01Q3/40 H04Q7/36

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01Q H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 38693 A (KARMI YAIR ;LIPMAN DAVID (IL); WEISS ANTHONY J (IL); WIRELESS ONLI) 3 September 1998 (1998-09-03) page 5-8; figures 1A-4	1-4,8, 10-14
A	US 5 008 678 A (HERMAN MARTIN I) 16 April 1991 (1991-04-16) column 4; figure 2	3
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A	WO 99 44297 A (ADICOM WIRELESS INC) 2 September 1999 (1999-09-02) figure 2	8

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 May 2001	16/05/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Ribbe, J

INTERNATIONAL SEARCH REPORT

Inte nal Application No
PCT/EP 00/08583

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/EP 00/08583

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